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PRINCIPLES OF SOIL EROSION CONTROL

by

Bureau of Agricultural Engineering

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Soil erosion is caused chiefly by the rapid movement of rain water down the slopes of the land surface. To control and prevent excessive erosion it is necessary to control the flow of the run-off water so that it cannot attain the velocity necessary to erode the soil over which it travels. Nature controls erosion largely by supplying a vegetative covering that slows up the run-off and permits a larger part of the run-off water to be absorbed by the soil. It is not until man, by artificial operations such as cultivation, overgrazing with livestock, lumbering activities, fires, etc. destroys the balance established by nature that excessive run-off and resulting soil erosion becomes a serious problem. Man must continue to cultivate the land, and he desires to grow the most profitable crops, taking into consideration the proper maintenance of the fertility of the soil. Therefore, some means must be developed to control the increased run-off and soil erosion which follow his activities.

The engineer, in studying the problems of soil erosion and its control, is primarily interested in determining the cause of erosion and developing remedies that will control the cause and thus prevent its occurrence. The rapid movement of rain water down the slopes of the land surface is the cause of the erosion. If all the rainfall were absorbed by the ground upon which it falls there would be no necessity for the control of erosion. The excess water that is not absorbed by the soil is the source of all water erosion control problems. The movement of this water is slow at first without power to do much damage but as it proceeds down the slope it gains increasing momentum and power to tear away the soil and produce gullies of increasing size.

The ability of water to cause erosion is dependent upon its velocity and the velocity of the water in turn depends upon the slope of the land and the volume of the water. Erosion is therefore more pronounced on steep slopes than on gentle slopes because the run-off water attains higher velocities and can therefore remove more soil. For instance, if the slope is increased four times, the velocity of the water is about doubled and the power of the water to carry away soil is increased about thirty-two times. Water flowing down a land slope tends to concentrate in small depressions on the surface forming streams which grow larger in volume approaching the foot of the slope. To illustrate, assume a land slope of only one percent - one foot fall in 100 feet - and that the water on the upper part of the slope flows in streams 1/2 inch deep and 3 inches wide; at the middle of the slope 2 inches deep and 3 inches wide; and at the foot of the slope 6 inches deep and 3 inches wide. The velocity in these three stream channels flowing full would be, according to the well-known Chezy-Kutter formula for computing velicities - 0.86, 1.82, and 2.40 feet per second. From this it is seen that the velocity of the water half way down the slope is about double and at the foot of the slope about three times the velocity at the top of the slope, and the power of the water to erode or carry away particles half way down the slope is 43 times and at

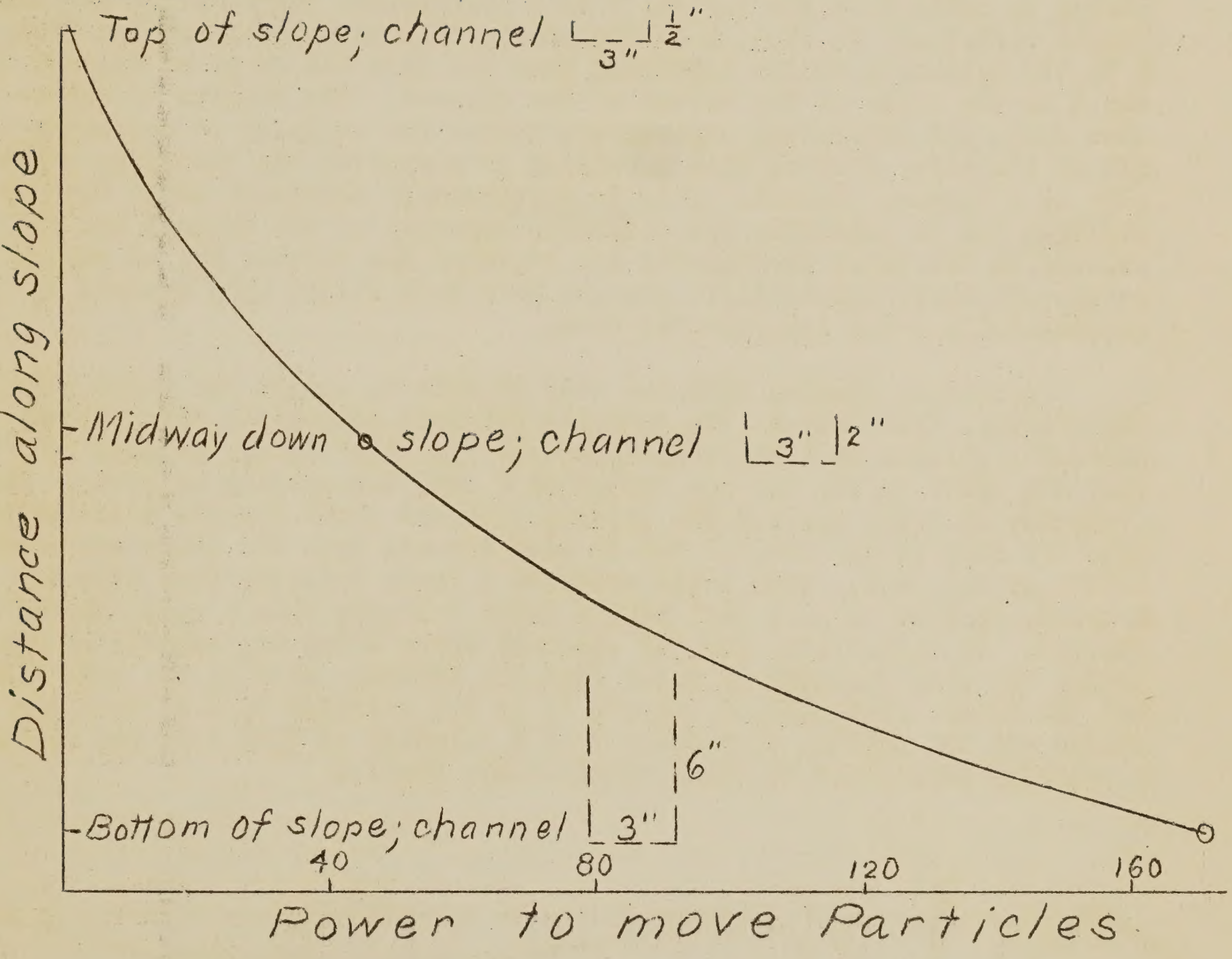
the foot of the slope is 170 times as great as at the top of the slope. this is shown graphically in the accompanying curve.

In order to prevent the development in size of such streams of water with the attendent increase in velocities and erosive power, it is necessary to intercept the water at intervals on the land slope. Controlling this run-off water is primarily a problem in hydraulics - a science which the engineer is trained to apply - and drainage, a branch of this science, is the key to the whole erosion control problem. In fact, erosion control is essentially properly planned hillside drainage, the construction of drainage channels on hillsides located in such manner that they will collect the run-off water and conduct it to a suitable outlet before it attains sufficient velocity to appreciably erode the soil. This method of hillside drainage, as developed by the engineer, is known as terracing.

The drainage channels which intercept the run-off water and prevent its rapid flow down the slope are formed by throwing up broad ridges of soil called terraces. In terracing land the first terrace is constructed near enough to the top of the hillside to collect the run-off water before it attains sufficient velocity to cause appreciable erosion and the remaining terraces below are spaced at suitable intervals to serve the same purpose. By giving the terrace a fall, the water that collects in the drainage channel is conducted along the terrace to the outlet ditch which is usually located along the edge of the field and so constructed as to be protected against erosion. The size and fall of this channel must be so chosen that the channel will be able to carry away the run-off water which is delivered to it from the drainage area between the terraces without the possibility of the water overtopping the terrace.

From the foregoing it is evident that terraces should be spaced close enough together to prevent the concentration of water and appreciable erosion on the land slope between the terraces. In the spacing of terraces, however, another important factor must be carefully considered and that is the ability of the terrace channel to carry away the run-off water which is delivered to it from the land slope between the terraces for the most intense rains that are likely to occur. The amount and rate of movement of the water that runs off between the terraces depends upon the nature of the soil, the vegetative cover, the land slopes, the amount and intensity of the rainfall, and the shape, length and size of the drainage area. The drainage area for any particular length is determined by the spacing of the terraces. Disastrous failures of terrace systems are often due to an excessively large drainage area between the terraces. Where the length of the terrace can not be controlled, owing to the lack of an available nearby outlet, it is then necessary either to reduce the spacing between the terraces in order to reduce the size of the drainage area between the terraces, or to increase the carrying capacity of the terrace channel.

As stated above, the amount and rate of run-off from the land between the terraced depends upon many factors. The result of many carefully conducted run-off experiments collected over a long period of years by reputable engineers, and long-time records relating to the amounts and

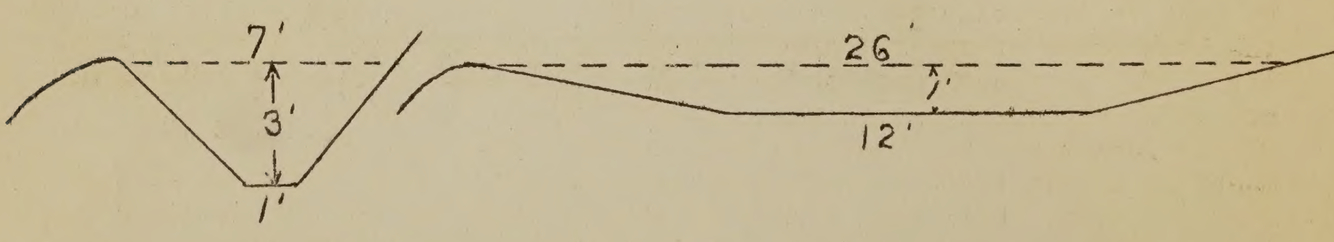


Curve showing increased power of water to move soil particles as it travels down slope.

intensities of rainfall, as collected by the Weather Bureau, furnish information indispensable to the correct computation of run-off from the area drained by terraces. With this information the engineer finds it possible to compute with accuracy the rate and amount of water delivered to the terrace channel.

The ability of a terrace channel to carry away the run-off water delivered to it depends upon the shape, the slope, the cross-sectional area, and the frictional resistance to flow. The discharge capacity of the channel is computed by the formula $Q = CA\sqrt{RS}$ where Q is the discharge in cubic feet per second, C is a coefficient representing the frictional resistance to flow, A is the cross-sectional area in square feet, R is the hydraulic radius depending upon the size and shape of channel and S is the slope of the bottom of the channel. The results of extensive field and laboratory experiments enable the engineer to determine all of the above factors with precision in computing the discharge capacity of a terrace channel. This is particularly important since terrace failures due to exceeding the discharge capacity of the channel and resulting in the water overtopping and breaking the terrace are of common occurrence where unscientific guesses have been relied upon instead of fundamentally sound experimental data.

A terrace channel must not only be able to remove the water from the drainage area between the terraces but must accomplish this without excessive erosion in the terrace channel. In other words, it must conduct the water to the terrace outlet at a low, non-eroding velocity. The velocity at which appreciable erosion will not occur depends principally upon the fall of the channel but it also depends upon the shape and erodibility of the soil. Some soils erode at a lower velocity than others. A broad, shallow channel will have a lower velocity than a deep, narrow channel. To illustrate, the two channels shown below are capable of removing the same quantity of water from the drainage area in the same time but the broad, flat channel removes it at low velocity of 2.07 feet per second and the narrow, deep channel at a velocity of 3.26 feet per second, a velocity sufficient to cause considerable erosion.



A = 12 sq. ft.
r = 1.28

V = 3.26 ft.per sec.
Q = 39.2 cu.ft.per sec

A = 19 sq. ft.
r = .73

V = 2.07 ft.per sec.
Q = 39.4 cu.ft.per sec.

The deep channel has a cross-sectional area of only 12 square feet as compared with a cross-sectional area of 19 square feet for the shallower channel. The shape of the channel alone, due largely to the fact that the line in the cross-section with which the water comes in frictional contact is only 9.4 feet for the deep channel and 26.1 feet for the shallow channel, is responsible for the small, deep channel carrying as much water as the large, shallow channel.

From the foregoing discussion it can readily be seen that considerable ingenuity must be exercised in planning terrace embankments on different land slopes so that the cross-sectional area of the channel will be sufficient to take care of the run-off water; so that appreciable erosion will not occur in the terrace channel; and so that the shape of the terrace embankment will not be such as to interfere with the easy operation of machinery in farming the embankments. The type of an embankment will necessarily not be the same on a steep slope of 15 percent as on a comparatively flat slope of only 3 percent in order to meet satisfactorily the foregoing requirements. Also, terrace embankments of different cross-section are required, depending upon whether farm operations are conducted parallel to or in straight lines crossing the terraces at any angle.

The height of a terrace determines largely the cross-sectional area of the water-way for any particular slope. The higher the terrace, however, the more interference with the operation of farm machinery. If the height of a terrace is kept low in order to meet farm machinery requirements, this may involve reducing the drainage area by a closer spacing of the terraces in order to prevent the run-off water from overtopping the low terrace embankment. Thus it is seen that the interdependence of all factors governing the design of a terrace is such that if a change in any one is made, readjustment of the remaining factors becomes imperative in order to restore the proper balanced relation of the various factors.

In constructing terraces, attention should be given to the type and condition of soil, in the same manner as is done in construction of highways, ditches, railway embankments, and other forms of earthwork construction. While terraces can be built satisfactorily on any soil, some study should be made to determine the best methods, the most suitable machinery and the best shape of cross-section for the terrace embankment for a particular soil. For instance, the heavy clay blackland soils in central Texas are much more difficult to work than the sandy clay soils in the Red Plains region of Oklahoma, and with certain types of small terracing machines nearly twice as much work is required to build terraces in the former region, while with larger machinery there is very little difference in the cost. Some soils tend to melt away when built into terrace embankments. Terraces in such soils require closer spacing, larger terrace embankments with flatter slopes, and less height and more attention to proper maintenance

The engineer is well fitted by education, training and experience to handle all sorts of construction work where an intimate knowledge of soils is essential to the success of the project, such as the building of levees, earth dams, and highway and railroad embankments, ditches, etc.

Cover crops and good crop rotations tend to reduce soil losses especially when used in connection with terraces. However, in any rotations where row crops such as corn, cotton, tobacco, etc. are grown, there are extended periods during which the land is not properly protected. Experiments conducted by the Bureau of Agricultural Engineering at Raleigh, North Carolina, during the years 1926 and 1927, showed that in that region during those years eighty-five percent of the annual soil loss resulting from erosion occurred during the four months, June to September, during which row crops are grown and cultivated; and that only fifteen percent of the annual erosion occurred during the eight months, October to May, which is the period of growing winter cover crops. Thus, in that region, any system of cover crops will be only partially effective in stopping erosion unless carried through the summer. In order to stop the heavy loss during the summer when the land is being cultivated, it seems evident that protection by terraces is necessary.

Terracing has been reduced by engineers to an essentially simple and easy farm practice. Necessary variations in specifications, resulting from differences in topography, rainfall, soils, and field operations, have been simplified until they are readily understood by the layman. At the present time terracing is being promoted by extension workers in twenty-two states. Eleven hundred thirty-two county agents reported terracing done by 48,716 farmers in 1931. During the past ten years approximately 15,000,000 acres have been terraced under the direction of the Extension Service. Terracing is a 4-H Club activity in fourteen states. This wide acceptance of the practice of terracing substantiates the results obtained on our soil erosion experiment stations which indicate that terracing is an effective and practical method of controlling soil erosion on cultivated land.